Report

in support of a nomination for

Lake Parramatta Dam

to be declared a

NATIONAL ENGINEERING LANDMARK

Prepared by

Ken Wyatt, Michael Clarke and Paul Heinrichs

for the

Engineering Heritage Committee
Sydney Division
The Institution of Engineers, Australia

Contents

Commemorative Plaque Nomination Form

Date: *August 3,1997*
From (Nominating Body): *Engineering Heritage Committee, Sydney Division*

To: Commemorative Plaque Sub-Committee, The Institution of Engineers, Australia
Engineering House, 11 National Circuit, BARTON ACT 2600

The following work is nominated for a:-
* National Engineering Landmark * ~~Historic Engineering Marker~~
* (delete as appropriate)

Name of work. *Lake ParramattaDam*
Location, including address and map grid reference if a fixed work.. *Off Lackey St., North Parramatta. Gregorys Map119, Ref B11*
Owner. *Parramatta City Council*
The owner has been advised of the nomination of the work and has indicated (attach a copy of letter if available) *that the nomination has the Mayor's support (see attached letter)*
Access to site *Excellent - the work is located in a public park, and is highly visible..*
Future care and maintenance of the work - *The work is under State government scrutiny.*
....
Name of sponsor..
For a NEL, is an information plaque required?....*Yes*..

Michael Clarke
....
Chairperson of Nominating Committee

Ken Wyatt
....
Chairperson of Division Heritage Committee/Panel

ADDITIONAL SUPPORTING INFORMATION

Name of work *Lake Parramatta Dam*
Year of construction or manufacture *1856*
Period of operation *1856- present*
Physical condition *Excellent*
Engineering Heritage Significance:-

Technological/scientific value	*Extreme*	Historical value	*V. high*
Landscape or townscape value	*V. high*	Social value	*V.high*
Contribution to engineering	*High*	Rarity	*Extreme*
Representativeness	*Moderate*	Integrity	*V.high*
Contribution to the nation or region	*High*	Authenticity	*V.high*

Persons associated with the work:: *Capt. P. Simpson, E.O. Moriarty, W. Randle, C.W. Darley*
Comparable works (a) in Australia *Nil* (b) overseas *Zola Dam, France*
Statement of significance, its location in the supporting documentation: *p.8*
Citation (70 words is optimum)

CONSTRUCTED TO A HEIGHT OF 11M IN 1856 AND RAISED TO 14M IN 1898, THIS FINE DAM SUPPLIED WATER TO PARRAMATTA UNTIL 1916. IT IS THE FIRST LARGE DAM AND THE FIRST ARCH DAM TO BE CONSTRUCTED IN AUSTRALIA. IT IS BELIEVED TO BE THE ELEVENTH SINGLE ARCH DAM IN THE WORLD AND ONE OF THE FIRST TWO DESIGNED MATHEMATICALLY. IMPORTANT PEOPLE ASSOCIATED WITH IT WERE ENGINEERS P. SIMPSON, E.O. MORIARTY AND C.W. DARLEY, AND THE CONTRACTOR W. RANDLE.

Attachments to submission (if any) *Nil*
Proposed location of plaque (if not at site) *On site, south bank abutment.*

Introduction

Parramatta Dam, completed in 1856 to supply water to the growing city of Parramatta, is one of the earliest arch dams ever built. It is recorded as eleventh in the succession of single arch dams constructed in the world since antiquity. The dam, which is 17.5m high and constructed of ashlar masonry, is contemporary with the Zola Dam (1854) in France, almost certainly designed according to the thin cylinder formula.

It is probable that Parramatta Dam was designed by Percy Simpson, although E.O. Moriarty also had a hand in design and was responsible for site supervision. The contractor was William Randle and the dam was extended in height by C.W.Darley in 1898. All four of these men played important roles in construction and civil engineering in the young colony of New South Wales.

The dam continued to supply high quality water to the town until 1916 (Fig. 1), and is now the centre of a recreational park. Modern analysis and regular inspection show that the structure is still capable of sustaining loadings up to the Probable Maximum Flood.

Because the dam and its features have been fully researched and described by others, this report will present only a brief summary of the history and technical features of the dam, relying for detail on the two attached appendices: *Lake Parramatta Dam - Its Place in the Evolution of Arch Dam Technology* (Appendix A) and *Parramatta Single Arch dam - From 1856 And Still Going Strong* (Appendix B).

Having summarised the historic, social, scientific and heritage significance of Parramatta Dam, this report concludes with a recommendation that its significance is such as to justify the Dam being declared a National Engineering Landmark.

Description

The original dam had a height of 11.0 m and a crest length of 80 m, with thicknesses at crest and base of 2.4 m and 4.5 m. respectively. (Appendix A). It was of single arch construction, having a radius to the upstream face of 74.55 m, with a storage of 280 ML derived from a catchment area of 7.6 km^2.

It was built in sandstone ashlar masonry in 15 courses above a concrete apron on the downstream side, and is believed to extend 3.6 m into the sandstone abutments of the valley. Original documents show that the stones were all dressed to templates. Recent tests have shown (Appx B) that the joints subject to the action of water were all formed in Roman Cement mortar and are still in excellent condition without major leaching or crystallisation. Portland cement was used in other parts of the works.

By 1892 the demand for water had outstripped the capacity of the pondage, and a decision was taken to raise the height of the wall by 3.3 m, using Portland cement concrete. This increased the height to about 14.5 m, the crest length to 97 m and the storage to 590 ML; the width of the concrete crest was now 1.55 m. Fig 2 shows a

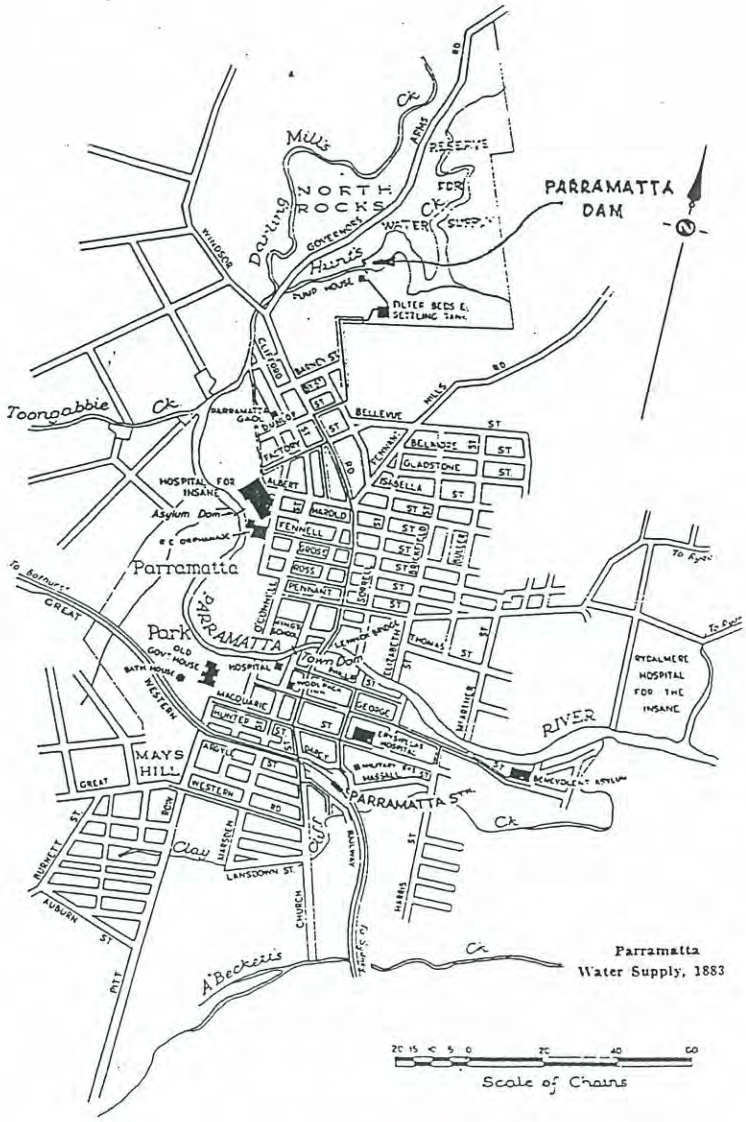


Fig 1: 1883 plan of Parramatta, showing location of Lake Parramatta Dam, and water supply at that time.
Source: Appx B

present-day cross-section through the wall, and Plates 1-6 show the dam as it presently appears.

Research by Ash and Heinrichs (detailed in the Appendices) has shown that the structure has a number of unique features. Most notably, it is believed to be the eleventh earliest single arch dam constructed since antiquity. "For its time Parramatta Dam is a remarkable structure, very slender relative to its predecessors, homogeneous by virtue of its close mortared joints, and apparently the first dam to incorporate Portland and manufactured Roman Cement in its construction. A comparison with its immediate predecessor Zola dam is illustrated in Fig 3. The Dam's slenderness in particular suggests a novel approach was used in its design." (Appx B).

History

Dams had been built at Parramatta in 1818 and 1831, but as the population increased the water supply quickly became inadequate and the Governor appointed a Committee of Water Commissioners (of selected Parramatta citizens) to carry out the construction of a new dam and water supply system. In 1851, the Committee approved a plan for a circular arch dam. Various tendering processes were undertaken without a start being made on the works before a new Committee called for fresh tenders to plans prepared by Captain Percy Simpson in 1853. Simpson was to be in charge of the works and a contract was let to Mr W. Randle (who was then completing the construction of the Sydney to Parramatta railway). At a later date, it was stated in the press that Mr E.O. Moriarty (a civil engineer in private practice) was the supervisor, and had also participated in the design. There still remains some uncertainty as to who was actually responsible for design.

Work was well under way in 1855, with the foundation stone being laid on 7 June. Moriarty was certainly in charge of construction for most of the contract, and Randle was the contractor. According to a contemporary report, a timber frame was erected "over the entire site of the dam at a height of thirty three feet; along this a travelling-jenny travels, and the operations of raising the blocks and lowering them in their destination are performed with the utmost precision." The dam was completed in September 1856 at a cost of 17,000 pounds. (Appx A)

By the 1890s the demand for water in Parramatta had so increased that supply had to be supplemented from the Sydney Metropolitan Water Board. In 1898, C.W. Darley (Engineer-in-Chief of Public Works) prepared a report proposing that the height of the dam be increased by 1.8 m; in fact, the height was increased by 3.3 m that same year by the addition of Portland cement concrete. In the process, the spillway was changed from the original bypass spillway to an overshot crest structure incorporating a syphon spillway for low flows. Darley subsequently went on to construct a series of thirteen slender concrete arch dams throughout rural NSW, which were the subject of the paper *Cylindrical Arch Dams of New South Wales, 1896-1908: "Work of a Courageous Nature"*, given to the 1990 Engineering Heritage Conference in Perth. .

In 1916, the dam ceased to be used for water supply purposes. Lake Parramatta is now part of a large recreational reserve, owned, managed and maintained by Parramatta City Council. Along with other local government dams in NSW, this Dam has been monitored and audited for safety by the Department of Public Works. In recent years,

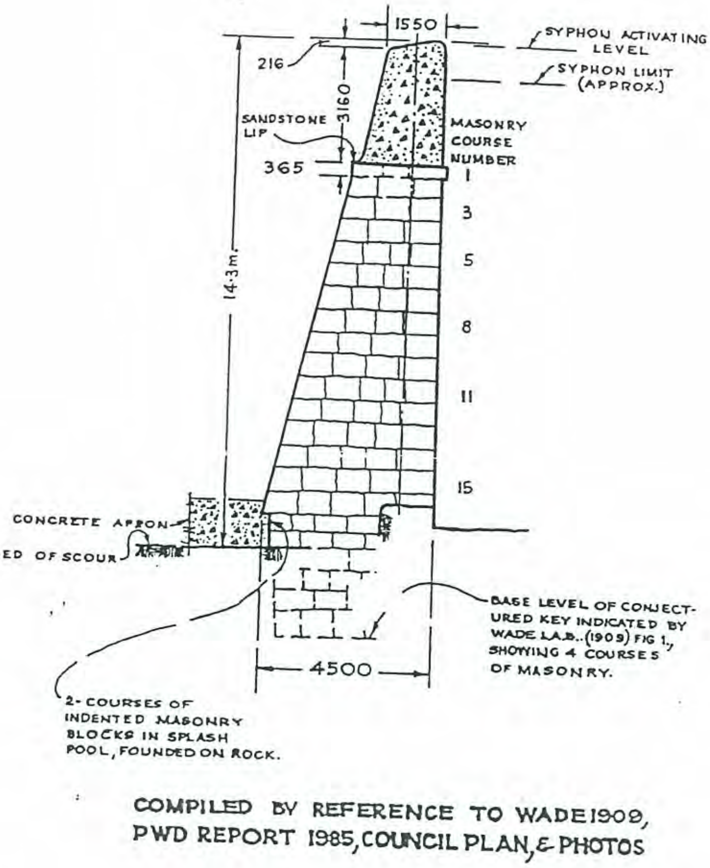


Fig 2:Cross sectional details at maximum section.
Source: Appx B

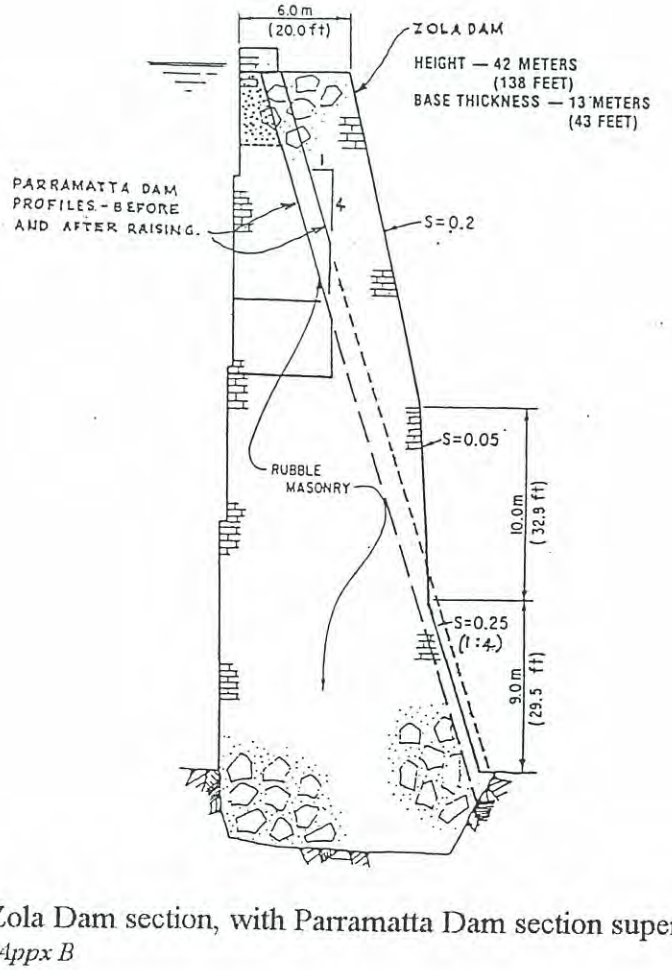


Fig 3: Zola Dam section, with Parramatta Dam section superimposed.
Source: Appx B

Public Works have made a number of investigations of the condition and safety of the structure. In 1995 a finite element analysis was undertaken (Appx 2) using data obtained from material tests made in 1982; these show that the dam can satisfactorily cope with storage at crest level, and that, although stresses exceeded allowable values at Probable Maximum Flood level, they were well less than ultimate stress.

Persons Associated with Design and Construction

The dam has technical associations with a number of prominent individuals from the nineteenth century: Simpson, Moriarty, Randle and Darley. Brief biographical details of these men follow:

Percy Simpson (1789 - 1877)

Captain Simpson was of Irish descent and served initially in the Royal Navy and joined the army in 1809. It is unclear what formal engineering training, if any, he received. In 1814, at the age of 25, he was appointed Governor of the island of Paxos in the Mediterranean. His regiment was disbanded in 1821, at which time Simpson appears to have held the rank of Captain.

He migrated to New South Wales in 1822, and in 1823 accepted a Commission from the Governor to establish a penal station and to determine the viability of wheat growing in the Wellington district. In 1828 Simpson became Assistant Surveyor of Roads and Bridges and was appointed Superintendent of construction of the most challenging section of the Great North Road. The massive dry-jointed retaining walls remain a testimony to Simpson's skill.

He moved to Parramatta in 1833, where he became Assistant Surveyor of Roads and Bridges, before being appointed Crown Land Commissioner. In 1839 he was appointed Magistrate of Patrick's Plains, and moved to Singleton in 1840. He travelled to London in 1843, and then returned to Parramatta, where he was involved in the design and construction of Lake Parramatta Dam from 1851 until at least 1854.

Simpson remained in Parramatta, practicing as a surveyor and as Registrar of Births Deaths and Marriages until 1870. He was responsible for no more engineering works after the Parramatta Dam, but leased a property on the McIntyre River and died in Sydney in 1877.

Source: Text of an address by R.R. Ash, Hills District Historical Society, 1995.

Edward Orpen Moriarty (1825 - 1896)

E.O. Moriarty trained in Dublin and Bristol before migrating to the Colony in 1848, where he initially worked on surveys in the Darling Downs. After returning to Sydney in 1849, he apparently established a private practice.

He joined the Department of Public Works NSW, in 1856 and became the first Engineer-in-Chief of the Harbours and Rivers Navigation Branch in 1858, a position he held for 30 years. Entrusted with all inland and coastal shipping facilities as well as dams and ferries, Moriarty shaped many of the harbours and river works of NSW. One of Moriarty's most important achievements was the design and construction of Newcastle Harbour, which was awarded a National Engineering Landmark in 1989.

From 1880, Moriarty was additionally responsible for Sydney's water supply. His Upper Nepean Scheme, later augmented by dams, was the city's main source of water until 1960, and is still in use. Historic Engineering Marker plaques were placed on three elements of the scheme in 1994 i.e. Prospect Dam, the valve house and the lower canal.
Source: *Historic Engineering Plaques of Australia*, Inst of Eng Aust, 1994

William Randle (1826-1884)
William Randle arrived in Sydney from England as a young man in 1852, having previously been a contractor on the Great East Railway. He became the major contractor for the Sydney to Parramatta railway, and commenced work on the project in August 1852. He remained with the project until its completion; the most important work for which he was responsible during this time was the Long Cove Viaduct, completed in 1855, claimed to be the largest civil engineering structure in the colony at that time.

Randle was involved in numerous heavy engineering works, including the Wollongong and Kiama Harbours and part of Circular Quay. He also constructed roads and residences in Sydney and suburbs. He was contractor for the Hobsons Bay Railway, Victoria from 1856 but incurred heavy losses; his debts amounted to over 38,000 pounds by 1862. He returned to England about 1868.
Sources: *Working the Clays*, Nora Peek and Chris Pratten, Ashfield and District Historical Society, 1996.
The Greatest Public Work - The new South wales Railways, 1848 - 1889, R. Lee, 1988.
A Biographical Register 1788-1939 - Notes from the name index of the Australian Dictionary of Biography

Cecil West Darley (1842 - 1928)
C.W.Darley emigrated to New South Wales from the United Kingdom in 1867 at the age of 25, having gained early experience on railway construction. He joined the Public Works Department and began work on the Newcastle harbour works under E.O. Moriarty, Engineer-in-Chief for Harbours and Rivers.

Darley served in Newcastle until 1881 when he became Principal Assistant Engineer, Water Supply, and while he held that position, many water supply works were constructed in the Colony. He subsequently succeeded Moriarty in 1889. Darley was appointed to the Metropolitan Water and Sewerage Board and was President in 1893. He was also Engineer-in-Chief for Sewerage construction for the Board.

In 1896 he became Chief Engineer for Public Works and retired in 1901. Under Darley's leadership, Public Works commenced in 1896 the construction of 13 thin arch concrete dams. They were of very economical form of construction and ensured affordable water supplies to country towns. These dams were designed and constructed by a team which included such notable engineers as L.A.B. Wade and E.M. de Burgh.
Source: *Landmarks in Public Works*, Fraser and L. Coltheart

Discussion of Heritage Significance
Statutory and non-statutory listings
At this time, the Lake Parramatta Dam has not been nominated with the Australian Heritage Commission for the Register of the National Estate.

The Dam is listed in the Register of the National Trust of Australia (NSW).

The Dam is not affected by any order made under the provisions of the NSW Heritage Act.

The Dam is noted by Parramatta City Council in the relevant Local Environment Plan..

Some Particular Considerations

There is no doubt that Parramatta Dam scores a number of national "firsts": It is listed by ANCOLD (Australian National Committee on Large Dams) as the first large dam to have been constructed in Australia. It is the first arch dam to be built in Australia. It is the only arch dam constructed of masonry blocks and Roman Cement in Australia. It is the forerunner of the set of thirteen arch dams constructed by the NSW Department of Public Works under C.W. Darley; these dams attracted world-wide attention following the presentation of a paper by L.A. Wade (who became Darley's successor at Public Works) to the British Institution of Civil Engineers in 1909. In world terms, it is a very early arch dam, and may be (together with the Zola Dam in France) one of the first two arch dams in the world to have been designed by a mathematical process.

It is believed these qualities alone are sufficient to justify consideration of this dam as a National Engineering Landmark.

Moreover, through the persons associated with its construction, the dam has strong links with other major engineering works of the period. Percy Simpson's work on the Great North Road; E.O. Moriarty's great harbour and river works (and, in particular, Newcastle Harbour, [NEL, 1989] and the Upper Nepean Water Supply Scheme [HEM 1994]); William Randle's construction of the Sydney - Parramatta Railway, especially the masonry bridges and viaducts; and C.W. Darley's pioneering work on arch dams [Medlow Bath Dam, HEM, 1994] - all these works interconnect with the Parramatta Dam to demonstrate a standard of quite outstanding quality, including stone masonry design and construction.

The attached letter from Mr Tony Moulds, Project Manager of the Heritage Dams Project of ANCOLD and the NCEH (Appendix C), mentions that, when preparing a nomination of this Dam for the Register of the National Estate, significance could be claimed for seven of the nine relevant categories. These are:

- The dam does have a strong association with an important development or cultural phase in the history of Australa.
- The dam is a rarity.
- The dam does have a research potential.
- The dam is a particularly fine example of its type.
- The dam and its reservoir does have a particular landscape or townscape value, aesthetic or environmental value.
- The dam does show outstanding creative or technical excellence.
- The dam or reservoir does have strong historical associations with nationally important figures.

In his letter, Mr Moulds goes on to say that in his opinion "the dam has national and international significance under a number of criteria, including engineering and technical significance. I have no doubt that it is a worthy contender for a National

Engineering Landmark plaque." He points out that the dam is ranked "third in importance in a selection of the top 26 dams in Australia".

Statement of Significance

The cultural significance of Lake Parramatta Dam is here assessed in accordance with the NSW State Heritage Inventory criteria by considering the *nature* of the significance (*historic, aesthetic, social, scientific* and *other*) and the *degree* of significance (*rare, representative* and *associative*). The cultural significance of this place is then seen to derive from the following factors:

- The dam is listed by ANCOLD as the first large dam built in Australia. *(Historic, scientific - rare)*
- It is believed to be the only masonry arch dam in Australia. *(Historic; scientific - rare)*
- The dam is believed to be the eleventh earliest single arch dam constructed in the world since antiquity. *(Historic; scientific - rare)*
- It is believed to be the only masonry dam in the world to combine the use of Roman and Portland cements in the one structure. *(Historic; scientific - rare)*
- It is of very slender construction when compared with structures of similar age. *(Historic; scientific - rare)*
- It was part of one of the earliest urban water projects in Australia, and remained in that service for sixty years. *(Historic; social; scientific - representative)*
- Its design and construction involved three of the most significant public works operatives of the time: Captain Percy Simpson, E.O. Moriarty and W Randle. *(Historic; scientific - associative)*
- The design of the dam is thought to have been a precursor to the use of the 'cylinder' formula used by C.W. Darley in his later program of dam construction. *(Historic; scientific - representative)*
- The raising of its height in 1898 by C.W. Darley was part of one of the earliest arch dam construction programs in the world, and attracted appropriate international attention. *(Historic; scientific - rare, associative)*
- The raising of height is itself nearly a century old and forms a part of the evolution of dam wall construction without unduly diminishing the integrity of the original structure. *(Historic; scientific - representative)*
- The quality of design and construction is demonstrated by the fact that the dam remains in excellent condition, able to withstand loadings caused by Probable Maximum Flood conditions. *(Historic; scientific - representative, rare)*
- The dam remains as the focus of an important social and recreational facility for Parramatta and surrounding district. *(Historic; aesthetic; social - representative)*
- It shows how technology can be adapted to provide an amenity which is valued by local inhabitants for its beauty, tranquillity and bird life. *(Aesthetic, social - representative)*

Recommendation

Having regard to all the factors addressed in this report, and, in particular, to -

- the importance attached to this dam by the Australian National Committee on large Dams *and*
- the international importance of a structure which is likely to be only the second mathematically-designed structure of its type in the world,

the Engineering Heritage Committee of Sydney Division recommends that Parramatta Dam be declared a National Engineering Landmark.

Proposed Wording for Information Plaque

LAKE PARRAMATTA DAM

CONSTRUCTED TO A HEIGHT OF 11M IN 1856 AND RAISED TO 14M IN 1898, THIS FINE DAM SUPPLIED WATER TO PARRAMATTA UNTIL 1916. IT IS THE FIRST LARGE DAM AND THE FIRST ARCH DAM TO BE CONSTRUCTED IN AUSTRALIA. IT IS BELIEVED TO BE THE ELEVENTH SINGLE ARCH DAM IN THE WORLD AND ONE OF THE FIRST TWO DESIGNED MATHEMATICALLY. IMPORTANT PEOPLE ASSOCIATED WITH IT WERE ENGINEERS P. SIMPSON, E.O. MORIARTY AND C.W. DARLEY, AND THE CONTRACTOR W. RANDLE.

DEDICATED BY THE INSTITUTION OF ENGINEERS, AUSTRALIA
AND PARRAMATTA CITY COUNCIL, 1997.

Bibliography

A full current bibliography is provided in Appendix B

Plate 1: General view of dam and catchment from south bank, looking upstream.

Plate 2: General view of dam and catchment from south bank, looking downstream.

Plate 3: Detail, downstream face, from south bank.

Plate 4: Detail, upstream face, from south bank.

Plate 5: Detail, downstream face, from north bank.

Plate 6: Detail, upstream face, from north bank.

Appendix A

LAKE PARRAMATTA DAM - ITS PLACE IN THE EVOLUTION OF ARCH DAM TECHNOLOGY

R.R.ASH

It is interesting to conjecture what were the influences and attitudes prevailing in the 1840s of last century towards the building of a "circular" dam for Parramatta Water Supply on Hunt's Creek. Parramatta is located about 25 km west of Sydney.

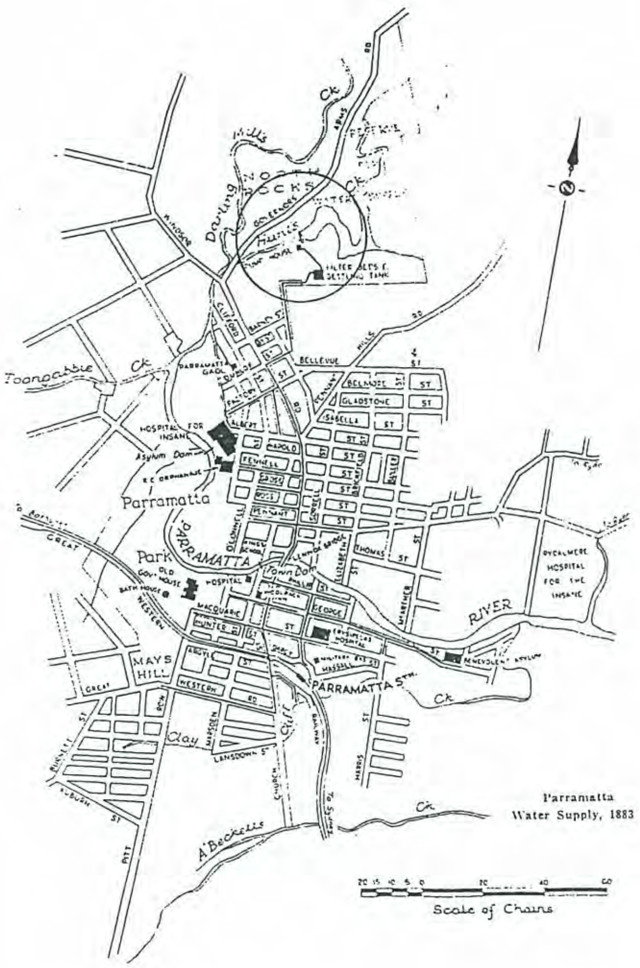


Figure 1. Parramatta and its Water Supply 1883 showing location of the Dam on Hunt's Creek (with acknowledgements to Sydney Water Board Journal).

R R Ash (retired) formerly Public Works Department of N.S.W. is a former ANCOLD Bulletin Editor.

ONE OF THE EARLIEST ARCH DAMS.

The project then envisaged was a major one in the scale of works being undertaken at the time in the Colony of New South Wales. It would be the first attempt at arch dam design and construction in this country, and seems to have been only the twelfth single arch dam built in the regions comprising Western Europe, the Middle East, the Americas and Australasia. The first of these was at Glannum in Southern France built by the Romans about 100 B.C., and the last before Parramatta was Zola Dam at Aix-en-Provence, completed in 1854. Up to about 1850, arch dams were not a popular selection by the veteran and historic dam builders, and this attitude persisted up to the turn of the century when C.W. Darley of the NSW Public Works Department began demonstrating the merits of this form of construction with his programme of some thirteen dams in New South Wales. (Wade, 1909)

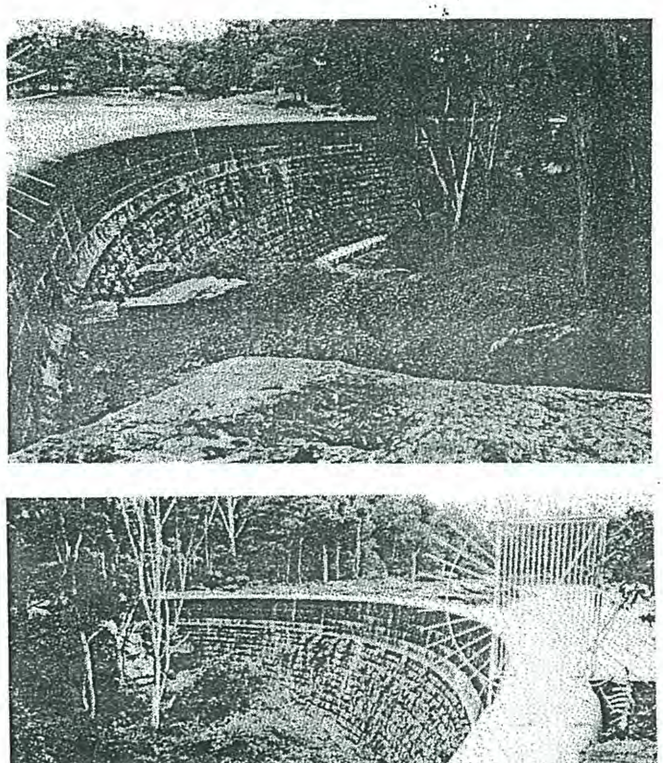


Figure 2. General views of the Parramatta Dam.

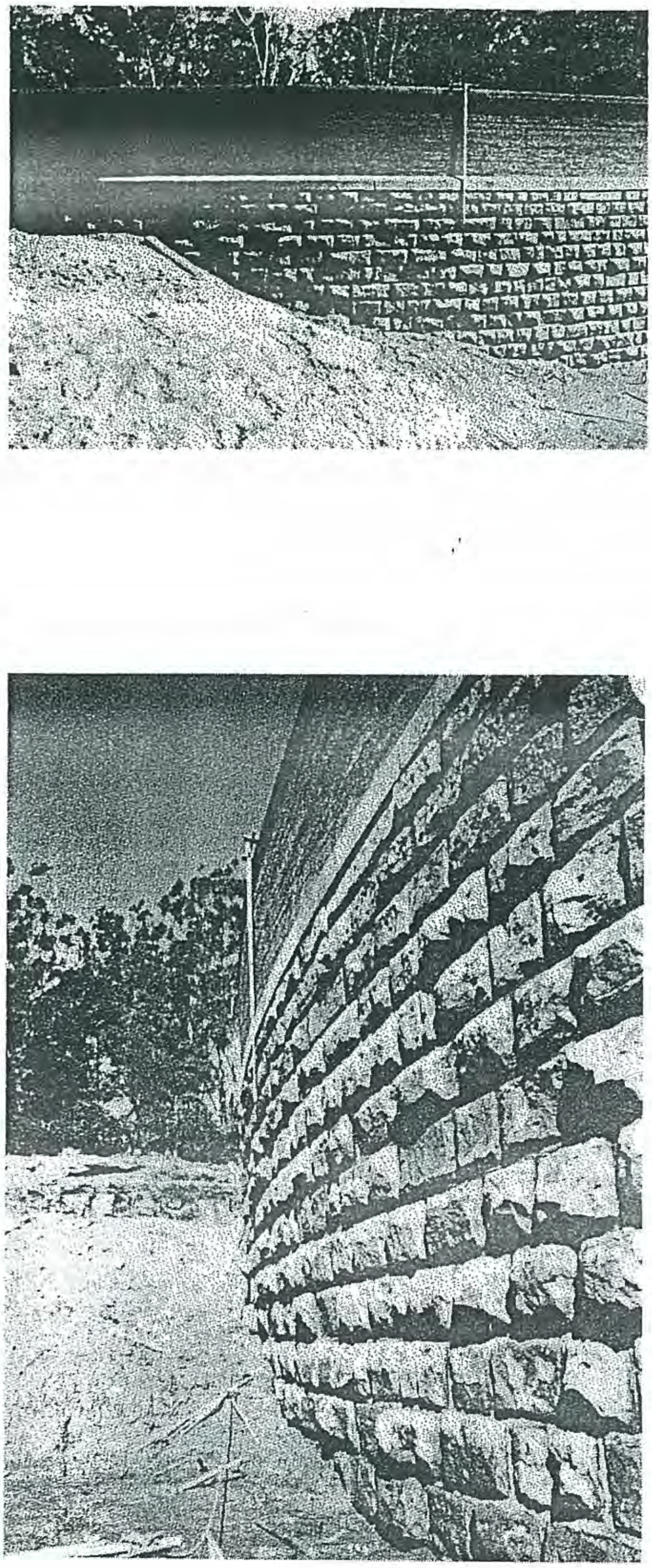


Figure 3. Two views on the upstream face, with storage drawn down for maintenance.

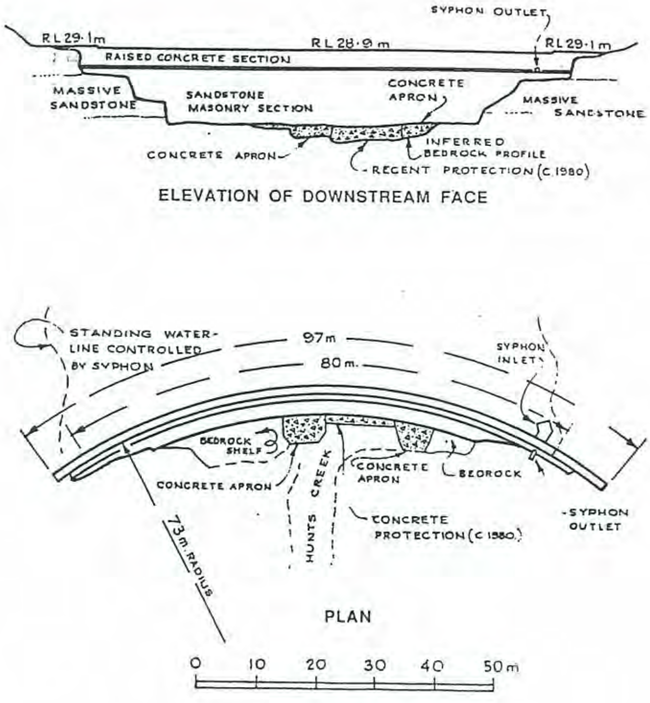
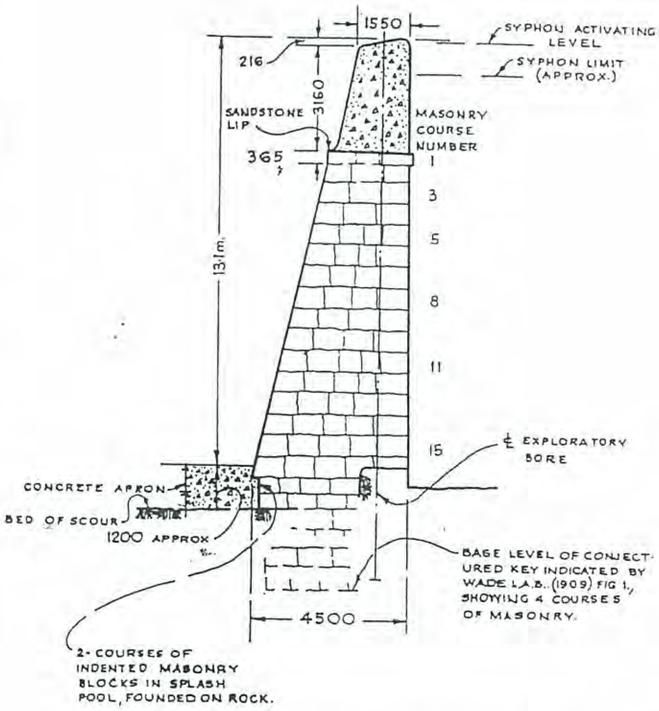


Figure 4. Plan and Elevation of the Dam.



COMPILED BY REFERENCE TO WADE1909, PWD REPORT 1985, COUNCIL PLAN & PHOTOS

Figure 5. Cross sectional details at Maximum Section.

CONTENTION OVER SITE SELECTION

So, the building of Parramatta Dam was an adventurous step. There had been a background of contention leading up to its execution. An alternative proposal at Toongabbie Creek had been seriously considered by the Committee of Water Commissioners charged with the responsibility for undertaking the work. However, the Hunt's Creek site at North Parramatta was finally adopted following a visit by Sir Thomas Mitchell, the Surveyor General who advised on selection of the Hunt's Creek site. Accordingly, the Water Committee on 22nd May 1851 gave its approval for the erection of a "circular" dam. Work was commenced, but problems and dissention again arose, leading to a reconstitution of the Water Committee.

The new Committee caused plans to be prepared by "Captain Percy Simpson, who was appointed Engineer for Works". (SWBJ 1954). Tenders were called in November 1853 and the dam was completed in September 1856. It is worth noting that Zola Dam in France was completed within this period, in 1854. Simpson may have been influential in earlier promoting the "circular" dam concept.

PERCY SIMPSON'S CONTEMPORIES

While Percy Simpson is recorded as having been appointed Engineer for the work, the supervision of its construction was later handed over to Mr Edward Orpen Moriarty, a consulting engineer in the Colony at the time. He was a Member of the Institution of Civil Engineers and later achieved renown as Engineer in Chief for Harbours and Rivers in the Public Works Department.

At the time decisions were being made leading to a "circular" or arch dam at Parramatta, engineers and others concerned with the building of major works in the Colony, were:-

* Sir Thomas Mitchell, Surveyor General. Mitchell ~~was a former Royal Engineer officer who~~ had been responsible for road and bridge building in the Colony among other things, and evidenced interest in engineering matters.

* Edward Orpen Moriarty M.I.C.E., an Engineer in private practice who had demonstrated great competence to Mitchell, early in his career, and later advised the Victorian Government on Yan Yean Dam.

* David Lennox, the noted arch bridge builder who was also highly regarded by Mitchell, and who had dealings with Percy Simpson during the course of their work (Selkirk 1920).

* Percy Simpson, a former army officer, but who was not of the Corps of Royal Engineers. Simpson had demonstrated great zeal and competence with the building and paving of roads, and for work on the Great North Road to Singleton, out of Sydney.

* Colonel George Barney, the highly regarded Colonial Engineer at the time.

No record has come to this writer's attention that Barney had any association with Simpson or the Parramatta Dam. Of them all, least is known about Percy Simpson particularly as to where and how he gained his technical competence.

19TH CENTURY DESIGN METHODS

In this period empiricism would have been the vogue, and formulae have been found for determination of the crown thickness of masonry bridge arches, which were the expert field of the artisan David Lennox. On the other hand, between about 1850 and 1900 efforts were being made to analyse arch dams, and the work of the Frenchman, M Delocre was notable in this regard. These early enquiries into arch action involved consideration of the cylinder formulae. Moriarty during the period of his indentures worked on the design and construction of several steamers of the highest class for the day (I.C.E. Obit. to Moriarty) and would no doubt have been familiar with the thin cylinder formula in this connection. It is perhaps worth noting here that Sir Thomas Mitchell left for England in 1853 to promote his discovery of a means of propulsion based upon "sound scientific principles" which, as was said on his departure, "... will add still further to your well earned reputation..." (Mitchell Lib. Rec.)

Last but not least, was the possible influence of the Zola Arch Dam completed in 1854 at Aix-en-Provence in France. It has been suggested the designer Francois Zola carried out calculations to select the form of his dam, and if so, Zola Dam would be the first arch dam for which design calculations were made. Perhaps Parramatta Dam was the second, but like Zola Dam, on what basis we do not know.

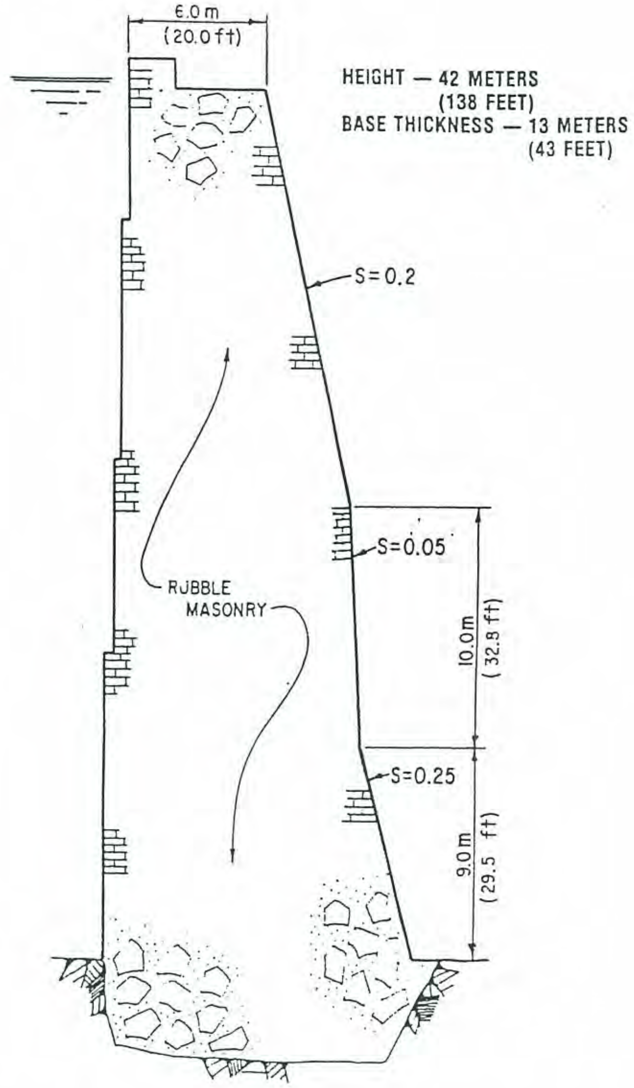


Figure 6. Zola Dam cross section for comparison with Figure 5.

PARRAMATTA DAM SIGNIFICANT AMONG EARLY ARCHES.

As mentioned before, our dam at Parramatta then appears in 1856 as No. 12 on the western world scene; this in itself is a noteworthy characteristic. As regards the eastern world, the U.S. Department of the Interior publication "Dams and Public Safety" suggests that historically, Asian communities had concentrated on earth and rock fill structures, and no record of single arch dams pre-dating 1850 have been found among them by this writer.

GEOMETRY AND FEATURES

Simpson's dam, standing on Hunt's Creek, a tributary of the Parramatta River, was originally built as headworks for the Parramatta town water supply. It now impounds a recreational storage in a reserve at North Parramatta and is owned by Parramatta City Council. It sits well on its site and still presents respectable proportions, as originally constructed, and following its raising in 1898 to Darley's recommendations (Wade 1909). It is appropriate to note here that the constructing authority for the 1898 raising was the then Parramatta Municipal Council, and that for the execution of the recent maintenance programme was the present Parramatta City Council.

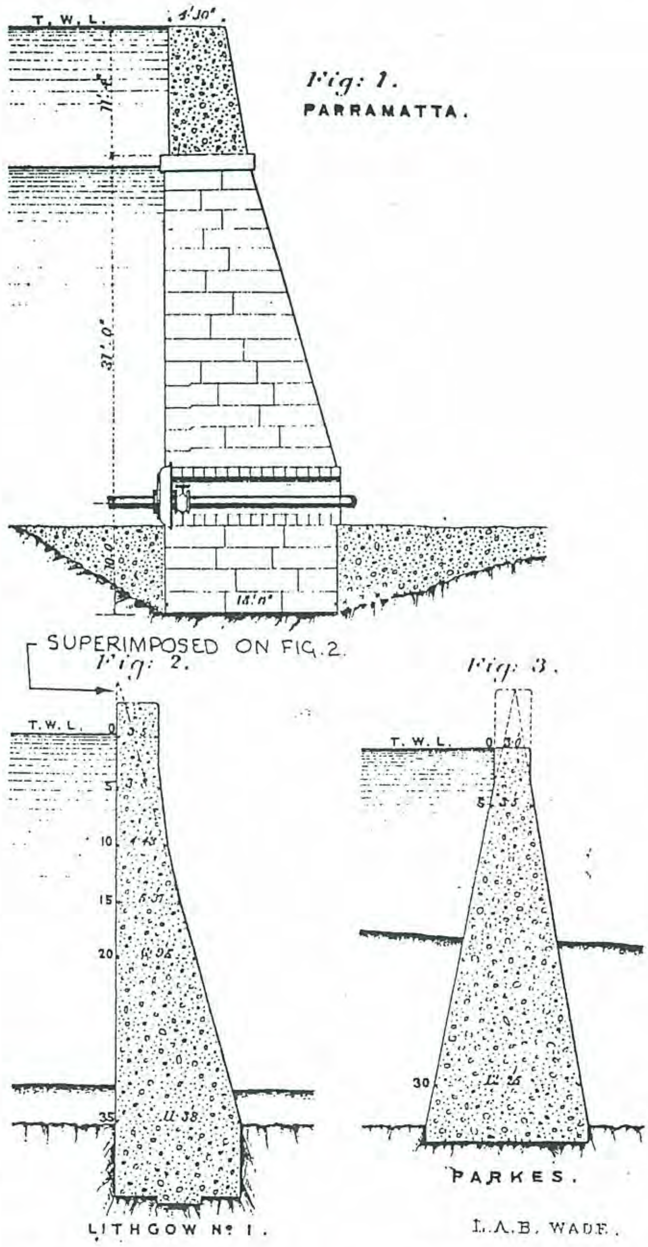


Figure 7. Reproduction of Figure 1. from Wade's paper of 1909 showing Section of Parramatta Dam also two other dams. Note P.W.D. "design triangle" on Lithgow and Parkes sections, also dimensioned height of Parramatta Dam (52 ft 4ins or 15.86 m).

The statistics of the dam as originally built were:

* Radius to vertical upstream face	74.55 m
* Length of crest	80.0 m
* Base thickness	4.5 m
* Crest Thickness	2.4 m
* Height	11.0 m
* Catchment	7.6 km^2
* Storage	280.0 ML
* Foundation and abutments - Hawkesbury Sandstone	
* Arch wall-masonry blocks set in Roman cement mortar	

The masonry block arch-dam wall of Parramatta Dam extended "12 feet" (SWB Jnl 1954) into the sandstone abutments of the valley. It was raised in 1898 by a 3.35 m concrete addition to the crest in accordance with a design directed by C W Darley, Engineer-in-Chief at the Department of Public Works at the time. The concrete addition to the original block masonry, makes the dam interesting.

The statistics of the dam after the raising, and as now existing are:

* Radius of upstream face	74.55 m
* Length of Crest	97.0 m
* Base thickness	4.5 m
* Crest thickness	1.55 m
* Height of present exposed downstream face (from scoured bed level of creek to crest level at wings)	14.5 m
* Catchment	7.6 km^2
* Storage	590.0 ML
* Arch wall - masonry block set in mortar with concrete raised section, 3.35 m high.	

FIRST ESSENTIAL HOMOGENEOUS ARCH

Of the 11 single arch dams in this writer's list which preceded the original Parramatta Dam (Glannum, Karrarine, Kebar, Daras Murcia, Elche, Relleu, Ponte Alto, Jones Fall, Zola, and Nero's Subiaco (accepting that this dam was an arch), only three have a better height to mean thickness ratio. These are Kebar in Iran and Ponte Alto in Italy which were built in deep narrow valleys, and Zola. The original Parramatta structure had a height to mean thickness ratio of about 3 which increased to in excess of 4 when the dam was raised; Zola Dam (Fig. 6) has a corresponding ratio. Of all these dams Parramatta was the first essentially homogeneous arch dam structure, by nature of its construction from shaped masonry blocks set in courses, with completely cement mortared joints.

PERCY SIMPSON

Now let us turn to look at Percy Simpson.

Andre Coyne (1956) in his paper on the Philosophy of Arch Dams says "there is nobody who can flatter himself on being the inventor of the arch dam, and there is quite a chance we will never discover how the whole set-up started". The arch dam has evolved rather than having been invented, and Percy Simpson and his associates were some of those involved in its evolution.

Simpson was born in 1787. He entered the Army and was a Lieutenant in the Royal Corsican Rangers, a Regiment of the British Army raised in the Mediterranean Theatre of the Napoleonic Wars in 1803. (J S.A.H.R. 1923). Troops were recruited locally, mainly in Corsica. The Rangers comprised some 1500 troops at maximum strength, and were engaged in Campaigns in and about Calabria and the Bay of Naples, and later in the Ionian Islands from whence the French were driven. The Regiment was entrusted with the provisional government of the Ionian Islands and remained there until 1817, when it was disbanded in Corfu. During this period Simpson was Local Governor and Advocate General on the Ionian Islands of Paxos.

It was not unusual for a Regiment such as Simpson's to be engaged in works, including civil works, as part of its occupational role. Simpson however, was not an engineer officer according to recent advice from the Corps of Royal Engineers.

SIMPSON IN NEW SOUTH WALES

Simpson went on to half pay in 1817 and migrated to N.S.W. arriving in Sydney on 8 November 1822. (McDonald 1968). He is reported as being "well connected" and carried letters of recommendation, and was appointed to command a new settlement at Wellington Valley in New South Wales, where it was intended to establish the viability of wheat growing. On 1st January 1823 he set off via Bathurst accompanied by his wife with soldiers, convicts and stores to undertake his commission. Simpson had not been permitted the services of any other officers to share his burden and was expected to fill the offices of Commandant, Chaplain, Commissary and Engineer (McDonald 1968).

Simpson succeeded in his task; by June 1826, he had 8900 bushels of wheat held in store, and had provided rations for

250 persons (McDonald 1968). He estimated that by February 1826 under his contract with the Government he was owed four thousand pounds sterling. Works carried out by him comprised several public buildings including the Commandant's house, a brick office and other buildings; a military barrack and gaol and an Engineers Department. There was also a Court, mill-room, grinding-room, missionary's cottage, lime kiln, workshops, hospital and a number of hutments. (McDonald 1968)

Demand from England for economy no doubt influenced the cancellation of Simpson's contract in May 1826; he staked his claim for payment in July 1826, but it was many years before it was settled by "negotiation' (Mitchell Library records).

Following his departure from Wellington he appears to have settled in the Hunter Valley where he obtained a grant of 2000 acres. In 1828 Simpson was appointed Superintendent on the Great North Road in an official capacity as Assistant Surveyor, and in 1833 became a Crown Lands Commissioner. He was appointed a Police Magistrate at Singleton in 1839, an office he held until 1843. (J Jervis about 1961).

SIMPSON AS ROAD BUILDER

Sir Thomas Mitchell had reported on Simpson as being "well acquainted with the process of road making". The Great North Road from Windsor to the Hunter Valley employed a work force of up to 520 convicts. It involved as well as pavements, massive dry-stone retaining walls and single span timber beam bridges with stone abutments, plus stone culverts and other drainage works.

Of all the Supervisors on the Great North Road, Historian Grace Karstens comments in correspondence (1984) that "Simpson and Finch were the best engineers on the Great North Road. They also had the most labour at their disposal".

Karstens reports (1985) on Simpson referring to "the improved system of road-making in England"; this together with his demonstrated achievements on the Great North Road and elsewhere suggests he was familiar with the new methods evolving from the road building revolution of the period.

He left the Great North Road works about 1833 and on 27 August 1833 the Sydney Gazette contained the following entry: "The road between Sydney and Parramatta, under the active superintendence of Percy Simpson Esq. is now in much better state than it has been for some time". The most significant work, however, which Simpson would have done relative to Parramatta Dam would have been the massive sandstone retaining walls (Fig. 8).

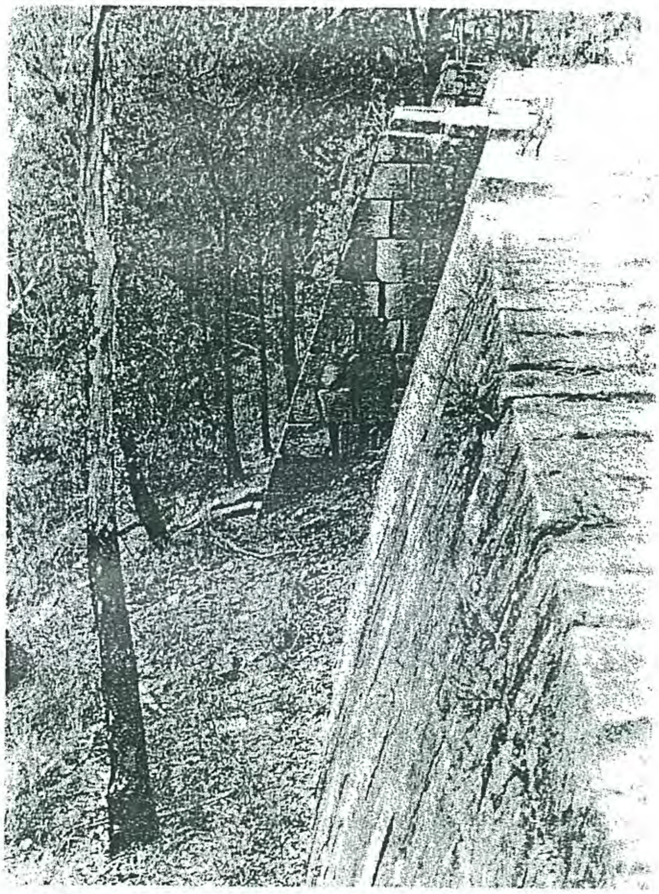


Figure 8. Dry stone retaining wall on Devine's Mill Great North Road, constructed under direction and Supervision of Percy Simpson (Reproduction of Figure 3. from the paper on Great North Road by G. Karskens).

Other brief facts from the Mitchell Library and elsewhere about Simpson are that he became insolvent in 1831 and was threatened with removal from public office on this account. He acquired 90 acres of land at Dundas on 25th July 1833 on which he constructed Oatlands House near Parramatta, and of present wedding-reception fame. Governor Bourke commended him in 1834 for his zeal and assisted him escape the insolvency charge. In 1842 he advocated the importation of cheap Indian labour into the Colony.

SIMPSON'S ABSENCE FROM COLONY

On 5th March 1843 Simpson left Sydney for London on the barque "Persian" ~~but this writer does not know where was his destination, or who he saw while away from N.S.W.~~ (Mitchell Library). One wonders if he took the opportunity to

confer with Zola or other French engineers with whom he or Mitchell might have established a connection during their Peninsular or Mediterranean Service.

In Januay 1847 the records state again that Simpson was absent from the Colony, ~~but again the matter of where he went is not known to the author~~.

While Simpson was a man of undoubted capacity, capability and courage, enquiries to date indicate he had no experience in dam building prior to his involvement with the Parramatta Dam; he was 69 when this was completed.

UNRESOLVED QUESTIONS; POSSIBLE ANSWERS

Some questions remain: What was the basis for the design; was this the result of one man's thinking, or was it a team effort; was it a development of what had been started at Zola and a step towards Bear Valley Dam in the U.S.A.

As to the design basis, three postulations can be considered:

* inspirational judgement
* empiricism
* application of the cylinder formula.

As to the first of these, the original crest was eight feet wide, surmounted by a four-foot high parapet. Eight feet would have been a convenient width for access, and the downstream slope of the wall was equivalent to the slopes used on the exposed face of the retaining walls on the Great North Road (Fig. 8). The 240 foot radius (73 m) chosen for the dam was considered in the appropriate range (up to about 300 feet) for an arch dam by investigators later in the 19th century (Garrett 1908-11).

The most conservative empirical formula for crest thickness of masonry arches (not originally intended for dams) which has come to attention is the square root of 0.17 times the radius, which produces a dimension of 6.5 feet. This could form a basis for the crest width of 8 feet (2.4 m) as finally selected, again using a downstream slope along the lines of those used on the Great North Road (Fig. 8).

With regard to a cylinder formula approach (T = PR/S), the dam does not have the geometrical profile used by the Public Works Department engineers for the dams designed at the turn of the century, and as described in Wade's paper. This, fundamentally, was a regular triangular section with apex corresponding to maximum water surface level and adjusted for crest width (Fig. 7), the application of the formula determining the dimensions of the triangle, and so the wall, commensurate with the design stress intensity adopted for any particular dam (see Fig. 7).

It is possible of course, that the thin cylinder forumla may have been used to determine the base thickness assuming a water level corresponding to original parapet level, standing four feet above the crest. With the mass of the original wall being 30 feet high, and the base 15 feet thick (S W B J 1954), the average stress determined from a water loading as above would have been 15 tons per square foot (1.6 MPa). The upper part of the dam might then have been proportioned from a need as seen to provide an access width of the crest of eight feet, or from incorporation of a slope in line with those being used on the roadwork retaining walls at the time.

The stress of 1.6 MPa just mentioned may be compared with allowable compressive stresses as recommended in the Public Works Department Safety Review Report of 1985, namely: 2.0 MPa for sandstone blockwork, and between 1.2 and 7.0 MPa for the rock abutments, depending on the quality and nature of the rock, in-situ.

CONCLUSION

We do not know how the original Parramatta Dam was designed but it stands as a monument to first class workmanship and for its day, visionary concept. It stands secure, after 130 years of service, and carries a load now after raising greater than that for which it was originally designed. Ironically the Lake Parramatta Dam is one of the few in the country which is now capable without modification, of safely passing a Probable Maximum Flood at its site. In practical terms, it could be the first homogenous arch dam structure ever built.

This paper is concluded with some philosophical comment.

In his book "The Fabric of Mind" (Penguin 1985) Richard Bergland draws the analogy of mountain climbing to mankind's challenging intellectual ascents in specific fields of knowledge. Each metal spike, or piton, driven into the mountain by the climbers defines the path by which the rope linked climbers ascend. Each represents a paradigm which lifts our understanding to a higher plateau, and so we may regard the Parramatta Dam as one of these.

Bergland goes on to demonstrate that these paradigms are almost always the

result of forward steps taken first by people acting alone, but of course we are not sure if this was the case at Parramatta. Drawing on the analogy again, however, progress is usually made when a lone scout returns with information about a new path. The scout must convince those in the base camp that it is time to move up. The debate will be carried on by the group (in the case of arch dams, through Bear Valley, Darley's New South Wales Dams, the work of Dureyea, Jorgensen and the other American pioneers, and so onwards).

Bergland points out that almost all the fundamental paradigms of progress appear as a result of pattern conscious thinking arising from the right side of the brain, often from people with scant education, and this writer likes to think of Percy Simpson as one of these, not that he was uneducated, but he was apparently quite inexperienced in dam engineering.

Parramatta Dam has been neglected in the literature to date, and it is hoped this humble contribution will stimulate academic interest in it, from engineers and historians alike, perhaps even to further test the dam against Bergland's theory.

ACKNOWLEDGEMENTS

The author gratefully acknowledges assistance provided to him in the preparation of this paper by engineering staff at the N.S.W. Public Works Department and Parramatta City Council, and also to Grace Karstens, Historian, and other correspondents. the permission granted by Parramatta City Council to use photographs provided, is also gratefully acknowledged, together with the permission of Ms Karstens to reproduce Fig. 3 from her paper on the construction of the Great North Road.

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First International and Eighth Australian
Engineering Heritage Conference
29 September - 2 October 1996, Newcastle Australia

Parramatta Single Arch Dam - From 1856 And Still Going Strong

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Summary Parramatta Dam, 17.5m high and constructed of ashlar masonry, was only the eleventh single arch dam built in the world since antiquity. It was completed in 1856 to meet the need for a 'wholesome' water supply for the rapidly expanding city of Parramatta.

No documented evidence is available as to who actually designed the dam, however it is contemporaneous with Zola Dam, based on the thin cylinder formula, built in France in 1854. There is some evidence that the dam was originally designed by Captain Percy Simpson who was responsible for the construction of many other notable works in early NSW including high masonry retaining walls on the Great North Road.

It is known that the dam was constructed by Randle who also built the railway line to Parramatta. Later the responsibility for the design of the dam was handed to E O Moriarty who would probably have had some formal knowledge of the thin cylinder formula. The dam was raised in 1898 by Darley. This was the forerunner to a programme of construction of 12 new slender arch dams in NSW.

Modern analysis and regular inspections of the dam indicate that it is capable of carrying loadings up to the Probable Maximum Flood, that it is in good condition and "still going strong".

1 INTRODUCTION

Lake Parramatta Dam, originally known as Hunts Creek Dam, owned by Parramatta City Council was completed in September 1856. It served as a water supply for the Town before Parramatta became a Borough, and prior to the establishment of any water supply authority in the Colony. As a result, the responsibilities for site selection and construction of the dam were given to a group of citizens appointed by The Governor known as the Committee of Water Commissioners (Aird 1).

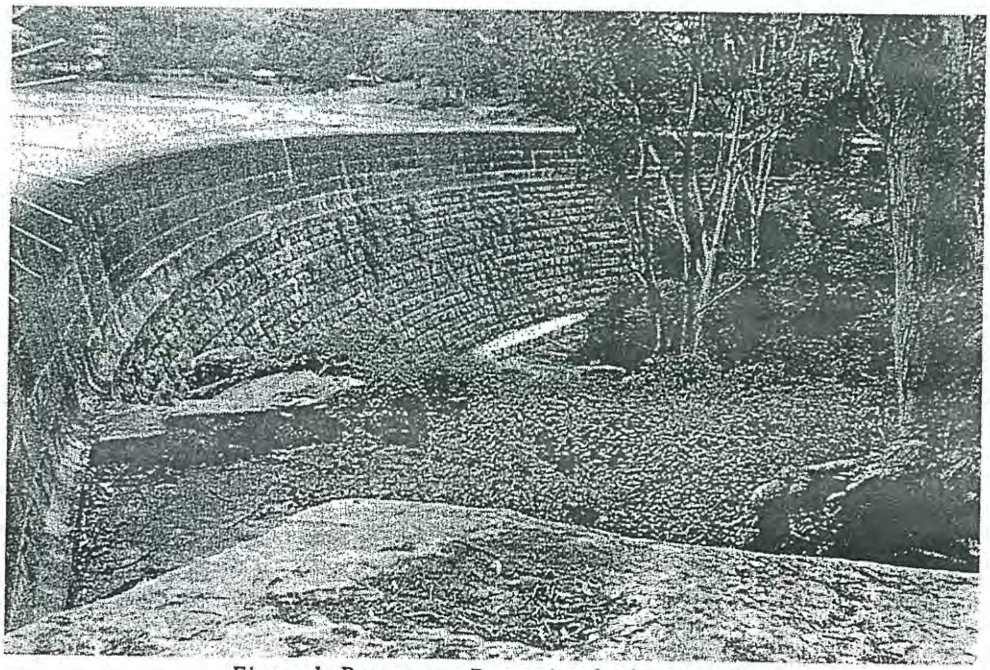


Figure 1: Parramatta Dam; view looking south.

The ashlar masonry Dam was raised with a concrete addition in 1898 to cope with increasing demand. It ceased to be a water supply dam about 1916, and presently serves as a recreational facility in the Lake Parramatta Reserve at North Rocks.

1.1 Parramatta and the Origins of the Dam

Parramatta is a commercial and residential satellite of Metropolitan Sydney with a present population of 135,000. It is located around the upper Parramatta River, 20 km from the Sydney C.B.D.

It was established in 1788, the same year as the First Fleet arrived in Port Jackson and was therefore an important centre right from the start, especially as the first wheat was harvested there in 1789 (Jervis 2), to support the new Colony.

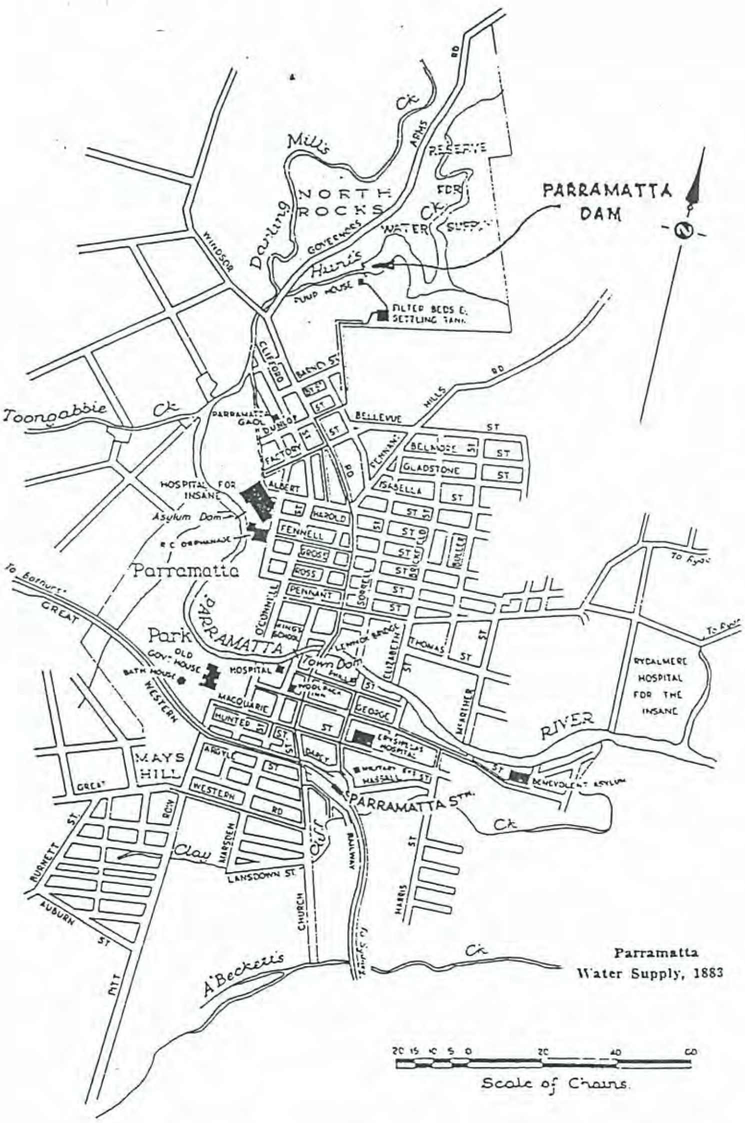


Figure 2: 1883 plan of Parramatta, showing location of Hunts Creek Dam, and Water Supply at that time (with acknowledgments to Sydney Water Board Journal).

The early Governors established a country seat at Parramatta and Governor Macquarie (1811-1822) developed one of its early residences into a fine Georgian structure as an alternative seat of administration.

In the early years three major institutions were established on the banks of the Parramatta river: a gaol, a hospital and a "Female Factory" for women prisoners. These along with other activities, seriously polluted the river behind, the low level Town Weir built under Macquarie in 1818 where Marsden Street crosses the river at the tidal limit. This impounded 140 megalitres from which the residents drew water by hand or water cart; wells were also used (2). In 1831, another dam was built adjacent to the "Female Factory" but this was subsequently carried away in a flood(1). The government institutions and dams in the Town are shown in an 1883 layout of Parramatta (Fig 2).

1.2 Agitation For A Pure And Reliable Water Supply

By 1847 the town's population had increased to 4500. Because of the pollution and recurring drought, the Government was asked to provide the district with a "full supply of pure and wholesome water". Unfortunately, due to other commitments at the time it was unable to comply (3).

According to Aird (1), in 1849 following much public agitation a meeting of citizens petitioned the Governor for a grant of £3000 to provide a wholesome water supply. A few weeks later the Legislative Council granted £1,000 to the citizens of Parramatta who were expected to find the other £2,000. The Government grant was later increased.

A Committee of Water Commissioners (the Water Committee) of selected Parramatta citizens was appointed by the Governor to carry out the work, and after much debate a site was chosen(4). On May 22, 1851, the Committee approved a plan for a "circular" (arch) dam on Hunts Creek. Mr John Stewart's tender for the work, of £1,150, was accepted, and preliminary excavations began in August. Shortly afterwards, however, Stewart turned in his contract. Two other contractors also abandoned the task. In 1853 the committee resigned, and a new committee called new tenders (in November 1853) to plans prepared by Captain Percy Simpson who was also "placed in charge of the Work"(2) and a tender was let to Mr W Randle. Aird (1) continues "Supervision of the work was given to Mr E O Moriarty...", but it is not stated when. Nevertheless, there is evidence Simpson was engaged on some early phase of the construction. On 25 August 1855 he wrote to the Editor of the "Empire"(5), saying that "...upwards of 4,000 cube feet had by me been previously laid in the foundation to the depth in the deepest part of 10½ feet".

The issue of who designed the Dam is clouded by the report in the "Empire" (6), on the laying of the foundation stone on 7 June 1855. It said that as a result of the Committee's deliberations "a design for the works produced by Mr T Moriarty, junr, has been approved of, and a contract for their immediate execution, by Mr W Randle, entered into". Also, when Governor General Sir N Denison visited the works on 24 August 1855, the Empire (7) reported him as referring to "... Mr Simpson, the former architect, and...Mr Moriarty, the present architect". Evidence that Moriarty superseded Simpson early on is confirmed by Moriarty's name appearing as "Engineer" on the commemorative plaque originally mounted on the parapet(8).

The authors presume that "T Moriarty, junr" and E O Moriarty are the same person. An inference from all the foregoing is that Randle's contract was renegotiated to construct the actual wall to a modified design, under Moriarty's supervision. In any case the work proceeded well in a period of high inflation, which caused the work to be suspended at one stage to await provision of extra funds. The Dam was completed in September 1856 at a cost of about £17,000 (1).

2 CONCERNING THE DAM ITSELF

The dam is a single arch structure, and only the eleventh such dam recorded since antiquity, according to Schnitter(9). He says its ten forerunners include Glannum, the first, built by the Romans about 100 B.C. in Southern France, the 700 year old Kebar Dam in Iran, some Spanish dams said to have arisen from the Moslem influence, Ponte Alto Dam in a narrow gorge in Italy, Jones Falls dam constructed by British Army Engineers in Canada, and lastly Zola Dam near Aix-en Province (1847-1854), almost contemporary with Parramatta Dam (1851 - 1856).

For its time Parramatta Dam is a remarkable structure, very slender relative to its predecessors, homogeneous by virtue of its close mortared joints, and apparently the first dam to incorporate portland and manufactured Roman Cement in its construction. A comparison with its immediate predecessor Zola Dam is illustrated in Fig. 3. The Dam's slenderness in particular suggests a novel approach was used in its design.

2.1 Physical Features

The dam's geometry, features and dimensions are shown in figures 4 and 5. Its catchment is 7.6 km^2. Before raising, the crest length was 80m, the crest width 2.3m and the storage 280Ml. A parapet 1.1m high of masonry set in portland cement mortar(8) sat above the crest. The water bearing part of the wall is set in "Roman" cement(8). After raising in 1898 with the 3.35m addition, the storage increased to 590Ml, and the maximum height from foundation increased from 14m to 17.5m.

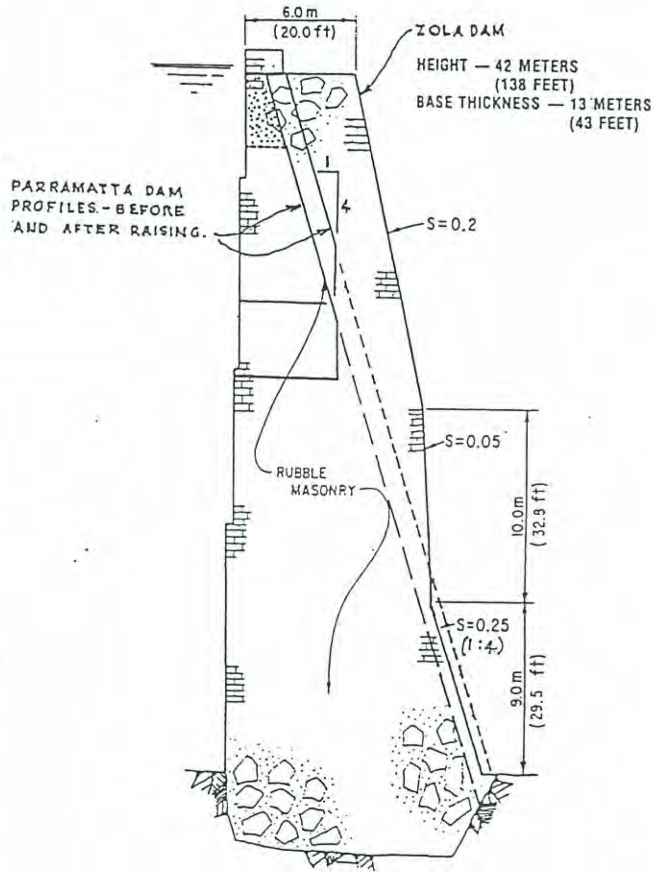


Figure 3: Zola Dam Section with Parramatta Dam Section superimposed.

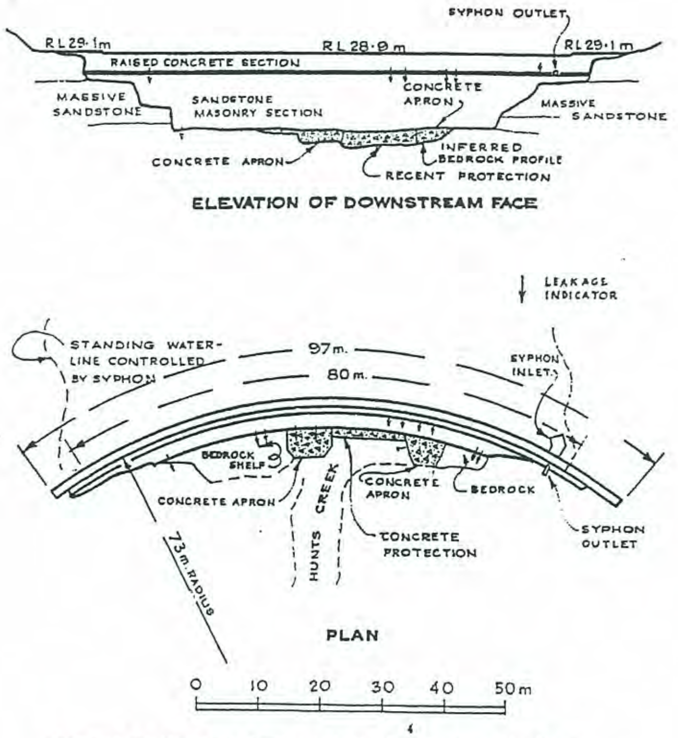


Figure 4: Plan and Elevation of Parramatta Dam.

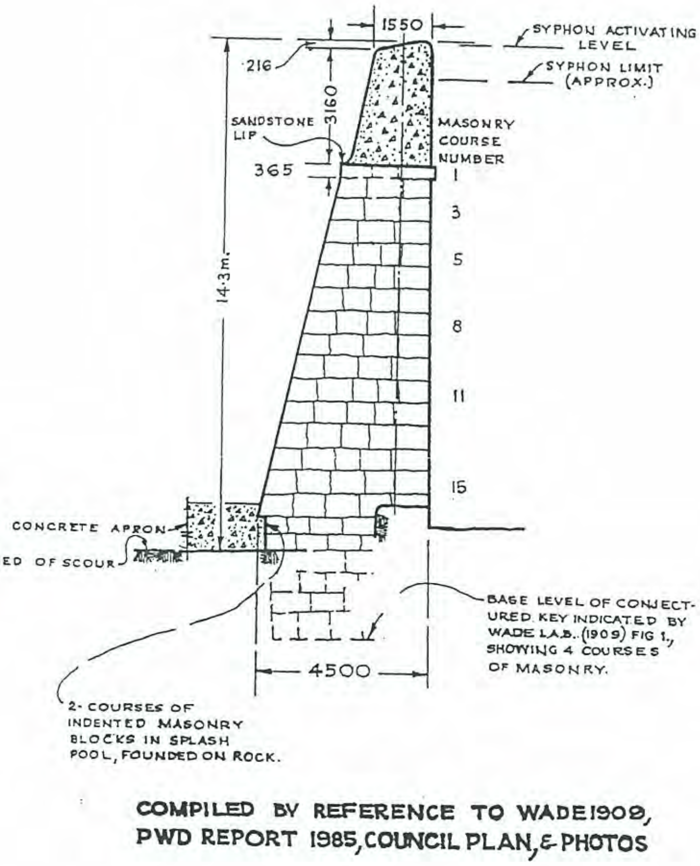


Figure 5: Cross Sectional Details at Maximum Section.

2.2 Statutory Requirements Relating to Dam Safety

Parramatta Dam, along with all other Council dams in NSW is subject to safety review, under the provisions of an amendment to the NSW Local Government Act of 1974. Thereunder the Department of Public Works was charged with the responsibility of carrying out safety surveillance of the dams and was responsible for auditing the safety of local government dams, (this responsibility recently transferred to the Department of Land and Water Conservation). Among these, Parramatta Dam was identified as having the highest priority for attention, due to its age and the hazard it presented to the population downstream.

2.3 Chestnut's Report

Accordingly, the Department completed a Safety Review of the Dam in 1979(10). This Report concluded that the dam was performing satisfactorily but recommended further investigations.

These investigations included a program of drilling and sampling of the dam and its foundations and a finite element analysis. The drilling and sampling was carried out by the Geological Survey of NSW, Department of Mineral Resources (Chestnut, 11).

A diagrammatic representation of the results is shown in Fig. 7. This indicated the foundation and abutment strata are essentially sound and that the weak zones present, make up only a small part of the total sequence.

The few weaknesses in the dam itself noted by Chestnut (11) were minor leaks and it was his opinion based on the investigation cores that the basal bond to the foundation strata is probably less sound than between the dams masonry and mortar and the dams masonry and the raised concrete section. It was reported that during the period of the dam's construction, when it reached a height of "16 feet" water was allowed to rise and flow over the dam and no leakage was discovered.

Chestnut stated the masonry blocks were in good condition and in general their rock substance was sound. The mortar jointing between the masonry courses showed no major evidence of leaching or crystallisation after more than 100 years.

2.4 Mortar Joints

This mortar used for jointing the masonry blocks is an especially interesting feature of the dam. Chestnut reports (11) probably the major feature from these studies is that manufactured Roman Cement rather than burnt lime or gypsum is the main cementing component in the mortar. This material forms a strong and dense product and probably explains the lack of leaching in the (permeable) in-service environment..."

The use of Roman Cement is confirmed by Moriarty in his paper (12), wherein he states "All the masonry...in the wall is set in Roman Cement, the stones having been carefully dressed to templates...". A contemporary report in the "Empire" Newspaper (8) states, "That portion of the work which is subject to the continual action of water has been set in Roman cement, and the remaining portion in Portland cement".

This account goes on to say a plaque was "inserted in the centre of the parapet and bears the following inscription" -

Erected A.D. 1856

Sir W. T. Denison, K.C.B., Governor-General

Supervision Committee

D. Forbes, P.M. | *J. R. Holden, J.P.*
James Pye, M.L.A. | *G.B. Suttor, J.P.*
C. W. Finch J.P. | *J. M. Gould*

E. L. Rowling, Secretary
E. O. Moriarty, Engineer
W. Randle, Contractor

Unfortunately, this plaque no longer exists!

From H. J. Cowan's paper on the history of concrete (13), it appears "Roman Cement" dates from the production of this material in England by James Parker in 1796 from clays containing veins of calcareous matter, while, Portland Cement was first produced by Joseph Aspdin in 1811 from separately occurring deposits of limestone and clay.

An intriguing question is who was the discerning person at Parramatta who chose or specified these different materials for their different functions in the Dam. Equally open to question is who decided on the novel concept for the Dam of such slender proportions with its relatively long radiused arch. This must have been decided before Simpson was commissioned by the Committee to prepare plans. A site with appropriate abutments would have had to be selected, and a quarry site chosen to yield sufficient stone of the right quality. Further the cement for the mortars would have had to be ordered from England with its six months delivery period by sea.

2.6 Construction of the Dam

Another interesting factor concerns the machinery for handling and placing the masonry blocks in the dam. Again, by whom it was devised we do not know but it was probably Randle, the Contractor (14). A description of the block handling machinery is given in the report of 8 June 1855 on the laying of the foundation stone(6), and is quoted below. Unfortunately no illustration can be found.

"The commencement already made, consists in the formation of a timber frame over the entire site of the dam, running at the height of thirty three feet; along this a travelling-jenny travels, and the operations of raising the blocks and lowering them in their destination are performed with the utmost precision. A weight of twenty tons may be moved by this machinery, but the power applied in the present work will probably range between two and six tons. The labour is now directed to the excavation of the sides of the ravine to form footings and abutments for the dam wall, and also to preparing and laying the courses. The circumstance of the water being at its lowest ebb is very propitious to the operations."

Associated with this was a rail line to transport the masonry blocks to the gantry, from the quarry near the Dam(6).

2.7 The Raising Of The Dam

Following completion of the masonry Dam in 1856, Parramatta's population increased, dry periods occurred and a need developed to raise the Dam. The supply became so inadequate that the Council sought an emergency connection from the Sydney Metropolitan Water Board in 1892, from the Board's supply at nearby Granville(1).

It has been reported that Engineering Professor W. H. Warren of Sydney University was requested in 1892 to advise on the raising of the Dam(1).

A report was also sought from C. W. Darley Engineer-In-Chief, in March 1898(1), that the height of the wall be raised by 1.8m. The wall was in fact raised by 3.3m in 1898 using Portland cement concrete.

This new concrete converted the Dam into an overshot crest structure incorporating a syphon spillway for low flows and resulted in the closing of the original bypass spillway, excavated at the Northern end of the original construction(8).

During the 1890's Darley embarked on his program of building twelve new slender concrete arch dams using the thin cylinder formula, for country town water supplies in NSW(15). The first was at Lithgow 1896, and Parramatta Dam raising followed in 1898. The likely influence of the unraised Parramatta Dam on Darley is discussed later in this paper.

3 WHOSE CONCEPT, WHOSE DESIGN

In his paper on the Philosophy of Arch Dams, Coyne(16) says "there is nobody who can flatter himself on being the inventor of the arch dam, and there is quite a chance we will never discover how the whole set up started."

Parramatta Dam is a landmark in the evolution of arch dams due to its slenderness, and its use of cement mortar, both "Roman" and portland in its joint and its construction. The most intriguing aspect is who actually conceived its form, or what analytical process was used in its design. It is interesting also that it is contemporary to the Zola Dam. Although not as high, Parramatta Dam shows some similarity in profile to the French Dam. The two are also common in that the basis for their design has not been established.

To investigate the concept for the design of Parramatta Dam the authors studied the background and experience of persons connected with its implementation. Notable among these was Percy Simpson who is mentioned as the Dam's designer by Aird(1) and Schnitter(9), however Edward Moriarty and the Contractor Randle were also involved.

3.1 Percy Simpson

Unless otherwise noted, the references to Simpson's early career outlined below are from (17) and (18). Simpson's background gives the author an indication of his competence. He was well known in his time. Born in 1789, into a well connected Irish family, Simpson served in the Royal Navy(19) and the Army and was posted in 1812 to the Royal Corsican Rangers during the Napoleonic Wars. When the Mediterranean Ionian Island of Paxos was captured from the French in 1814, Simpson was appointed Governor.

Paxos is a small rocky island. An article (20) mentions that "walls have been built everywhere". Many roads which traverse the island are very likely a legacy of the British during their occupation as, they were credited with extensive road building throughout the Ionian Islands(17). No doubt Simpson made a contribution on Paxos.

Simpson's regiment was disbanded in 1817. In 1822 he migrated to New South Wales with his wife and two children. Prior to migrating he wrote to Earl Bathurst claiming his knowledge of Surveying and road making might be useful in the new Colony (Karskens 21).

On arrival, he accepted a Commission from Governor Brisbane to establish a penal station and to determine the viability of wheat growing in the Wellington Valley (AHR).

In January 1823 Simpson took 250 convicts and soldiers to the Valley, where for 3-1/2 years he was Station Commandant, Chaplain, Commissary and Engineer.

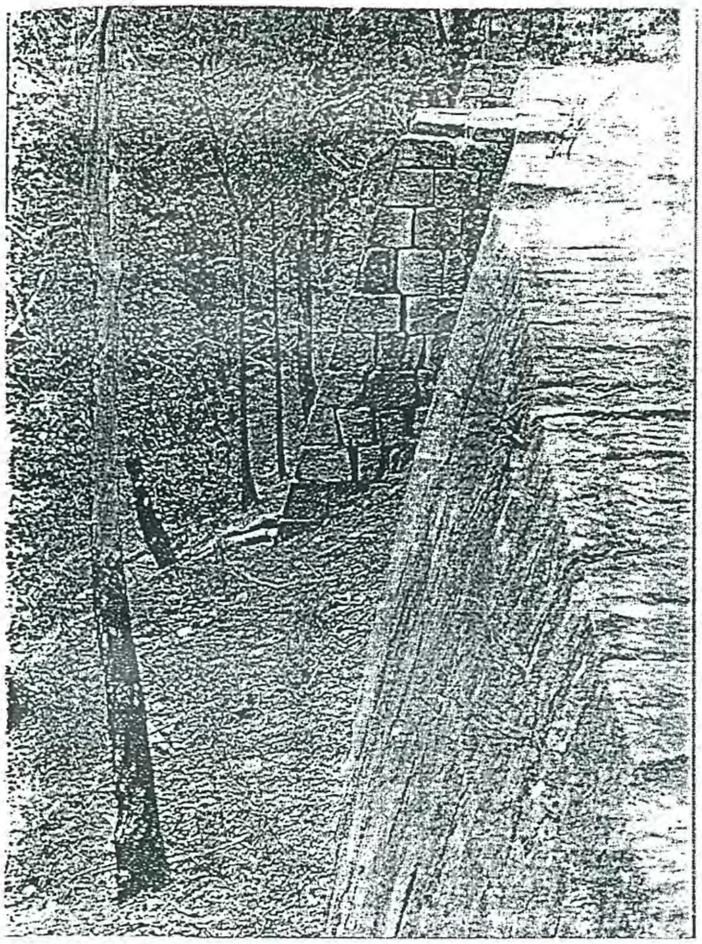
During this period, he demonstrated that wheat could grown at Wellington, and he laid out a plan for a town. He was however unhappy with the remunerative terms of his contract and claimed an additional payment of some £4,000. The Government had refused and an impasse had developed. He had made successive claims and travelled to London in 1843 and 1847 to press his claim directly with the Colonial Secretary.

Figure 6: Present-day Paxos.

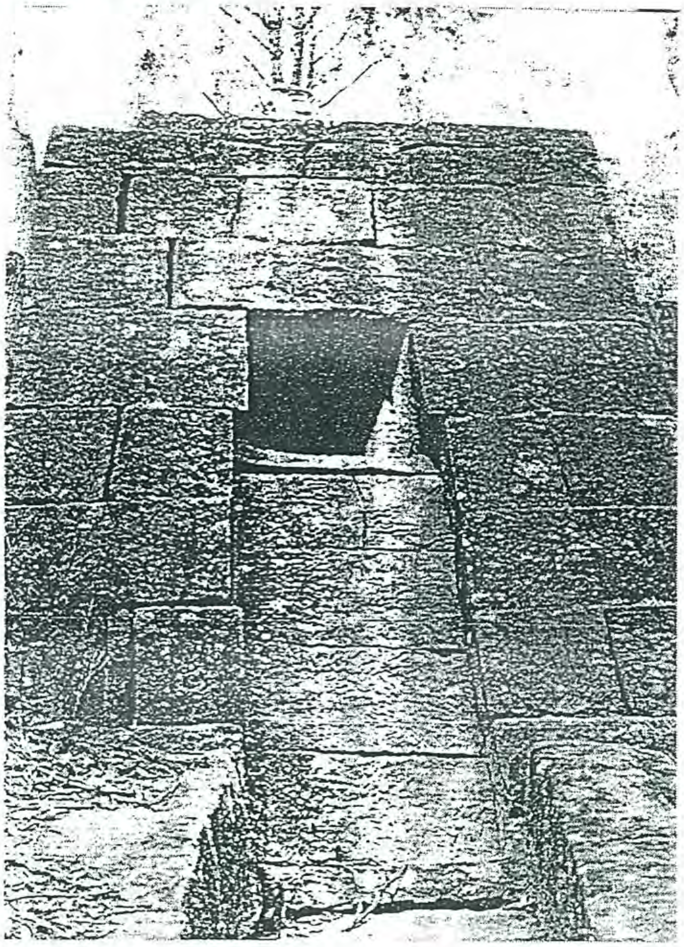
In 1828 Simpson became an Assistant Surveyor of Roads and Bridges and was appointed Superintendent of the extremely rugged part of the section of the Great North Road from Sydney to the Hunter Valley where it crossed part of the Judge Dowling Range.

Karskens states (21) Simpson, over a four year period "Superintended up to 700 convicts...and designed a road which scaled steep rocky valleys.... The formation at Devines Hill was supported by ashlar masonry retaining walls at one point heavily buttressed and drained by systems of tremendous variety...". It might be noted that while the masonry of the Dam is mortar jointed, dry jointing was the mode used for structures on the Great North Road.

Fig 7: Masonry Structures - Great North Road (Courtesy of Grace Karskens, Historian)



i) Buttressed Retaining Wall



ii) Culvert Outlet

Simpson then came to Parramatta in 1833 and the Sydney Gazette of 27 August 1833(22) records that "the road between Sydney and Parramatta under the active Superintendence of Percy Simpson, Esq. is now in much better state than what it has been for some time". His position then put him in charge of the Parramatta Depot where he was appointed as a Crown Lands Commissioner. In 1839 he was appointed Magistrate of Patrick's Plains (Singleton), and moved there in 1840. This Magistracy became redundant in 1843, and he then travelled to London.

While at Parramatta he reported on the need for a new bridge in Church Street (23)and had a difference of opinion with the arch bridge builder, Lennox over the span required. Lennox prevailed.

The authors note that Simpson's extensive experience, did not include any activity associated with dams. Nevertheless a man with his demonstrated talent could well have been gifted with the necessary inspirational judgement.

3.2 Simpson's Influence On James Pye

James Pye, a prominent Parramatta Citizen, appears as the dominant member of the Water Committee. E. J. Statham in "Parramatta Water Works" 1921 states (24) that Pye and Simpson were neighbours in Pennant Street, Parramatta, after Simpson returned from Patricks Plains. Possibly E. J. Statham was the son of The Statham who was a contemporary of Simpson, present at the laying of the foundation stone(6). E. J. Statham said "The moving spirit behind Mr Pye was Captain Percy Simpson, a retired military engineer. Simpson took the matter up very enthusiastically and brought to bear on it a mature experience and scientific attainments of no mean order...He designed a structure on lines substantially as subsequently carried out."

3.3 Other 'Designers'

i) Houison

The Sydney Morning Herald, 5 March 1851 (4) reports that "The plans and specifications for the proposed works were gratuitously furnished by Mr Houison, one of the Committee, and were favourably received by His Excellency, The Governor". It continues, "tenders were called but not proceeded with because of a problem with land acquisition". No copy of these plans and specifications have been found. Houison was an architect and builder and Parramatta's St Johns Church was a project of his (2).

ii) Moriarty, Randle And Darley

His obituary (25) records that Edward Orpen Moriarty (1824-1896) graduated B.A. and M.A. in Dublin. He was an articled pupil in Bristol, where he worked on the design and construction of steamships. Other experience embraced a breakwater and railway works. In 1848 he migrated to New South Wales, being employed by the State on Surveys in the Darling Downs. He came to Sydney in 1849 where he established private practice working among other things on the "Supervision of Hunts Creek Dam". Presumably he was aware of the thin cylinder formula, as applied to marine pressure vessels.

Randle, the Contractor presumably the same William Randle who built the Railway from Sydney to Parramatta, arrived in Sydney 9 July 1852 (14). His offer of contractual services was taken up by the Railway Company, and he achieved outstanding progress using the "modern methods" of shifting spoil in wagons on. rails. In August 1855 at a banquet commemorating the trial run to Parramatta and back, a toast to Randle, described him as able to do anything on the shortest possible notice from drainage of the domain to the taking of Sebastopol." He demonstrated this by taking on a second contract to build Parramatta Dam following the calling of tenders in November 1853.

Cecil West Darley born in Ireland in 1842 arrived in Sydney in 1867, joined the Public Works Department as an Engineer and worked under Moriarty as principal assistant engineer (26). While in that position "many of the water supply works in the Colony were constructed"(26). It is presumed that he and Moriarty would have had discussions about Parramatta Dam. Darley is renowned for the thirteen arch dams built to his direction in New South Wales at the turn of the Century, described by Wade (15). Schnitter (9) notes that "When Darley started construction of his arch dams he could not only rely on the example set by Parramatta Dam" but also on the Bear Valley Dam in the U.S. The latter is renowned for having been designed in the 1880's using the thin cylinder formula. Darley's 13 arch dams, including the raising of Parramatta Dam by 3m, attracted world attention, and helped popularise this form of construction.

Based on the above, the authors have noted the following points about the main players. They believe Simpson had the best combination of maturity and general experience, including his particular experience in heavy rock walling, and his surveyors skill in seeing the suitability of a site to a particular purpose. Randle seems to have had a gift for innovation and was perhaps more knowledgeable in technology advances such as the use of cements. Moriarty had a good formal education, perhaps the best among the group, and may have seen how the thin cylinder formula could be applied to this form of arch from his works on ship building.

3.4 Possible Sequence of Events

The authors conjecture as follows:

- The Committee approved adoption of a "circular" dam on 22 May 1851 at the suggestion of Simpson, and it was to his conception.
- The "preliminary works" following Stewart and others included foundation excavation to the 73m radius, and the placement of some foundation rockwork (Fig 5). Simpson probably was involved.
- Simpson prepared plans and specifications at the Committee's direction during 1853, sizing the dam with by wash for maximum development of the site, but to a design method not disclosed.
- Moriarty influenced the Committee to vary the cross section of the dam, prior to the calling of tenders in November 1853, and succeeded in having Simpson replaced by himself as Engineer of Works.
- After letting the Contract to Randle, Moriarty (or Randle) suggested a variation to incorporate cement mortar joints and this was adopted.
- The cements were ordered from England between the end of 1853 and June 1855 when the foundation store was laid. During that time Randle erected his gantry.

4. ANALYSIS OF THE DAM

4.1 Original "Design"

It has been speculated by Ash (27) that the "cylinder formula", relating the resistance of a cylinder to crushing pressure, derived by Navier in 1826 as $T = \frac{RP}{S}$, where:

P	=	Water pressure in tons per square foot
S	=	Safe crushing strength of material per square foot
T	=	Thickness at any point in feet
R	=	Radius in feet

may have been used in the sizing of this dam.

Unfortunately, there is no documented evidence known to the authors that this was the case. However, Ash (27) reported that based on this formula and "with the mass of the original wall being 30 feet high, and the base width 15 feet thick, the average stress determined from a water loading as above would have been 15 tons per square foot or 1.6MPa".

This stress compares favourably with the allowable compressive stresses recommended in Public Works Safety Review 1985 (28) of 2.0MPa for sandstone blockwork and between 1.2 and 2.0 MPa for rock abutments. This would tend to indicate that knowingly or otherwise the dam's sizing was made to comply with the formula.

4.2 Modern Analysis

As the dam has been determined by dambreak flood studies (28) to be a HIGH hazard, i.e., lives would be expected to be lost if it were ever to fail, a number of safety reviews and analyses have been carried out by NSW Public Works (10), (28), (29), (30), to determine the dams safety. These investigations included drilling, sampling and testing of the wall and foundations and 3-dimensional finite element analyses. The latest of these, completed in December 1995 by State Projects Division (now Client Services) (30), considered among others the following load cases:

i. Reservoir at Crest level
ii. Reservoir at Probable Maximum Flood level (2.35m overtopping) in conjunction with a tailwater depth of approximately 10m.

The finite element package STRAND 6.15 was used on a model based on a linear elastic structure with linear material properties derived from the 1982 (9) test results. Some key material properties are given in table 1 below

Material	Properties	Value
Concrete	Unconfined Compressive Strength (MPa)	34.9
	Allowable Strength (Mpa) Normal Load	13
	Ultimate Tensile Strength (MPa)	1.1
	Allowable Tensile Stress (MPa) Normal Load Extreme Load	 0.44 1.1
Massive Sandstone (Abutments)	Unconfined Compressive Strength (MPa)	31.2
	Allowable Strength (MPa) Normal Load	9
	Allowable Tensile Stress (MPa) Normal Load	0.3
Weak Sandstone (Abutments)	Unconfined Compressive Strength (MPa)	5.9
	Allowable Strength (MPa) Normal Load	1
	Allowable Tensile Stress (MPa)	0
Sandstone Masonry	Unconfined Compressive Strength (MPa)	7.8
	Allowable Strength (MPa) Normal Load	2
	Allowable Tensile Stress (MPa) Normal Load	0.16

Table 1: Key Material Properties Used in Finite Element Analyses.

The study found the following:

i. Under Normal Load

Compressive stresses in the dam (up to 0.7Mpa) are much less than the allowable compressive stresses of the different material components of the dam.

Moderate radial tension (up to 0.2Mpa) exists at the bottom of the dam along the heel. These slightly exceed the allowable tensile stress for sandstone masonry but are well below the ultimate tensile stress. Minor cracking of the floor could result.

Slight vertical tension (up to 0.14mpa) exists in the downstream face but this is less than the assumed allowable tensile stress for sandstone masonry.

The dam can therefore satisfactorily cope with the storage at crest level although some minor cracks could develop.

ii Under PMF Loading

High tangential compression exists at the upstream face near the crest and moderate compression exists at the bottom of the downstream face. These stresses however are lower than the allowable compressive stresses.

Radial tension at the upstream heel exceeds the allowable tensile stress for sandstone masonry but is much less than the ultimate tensile stress. Slight vertical tensile stresses exist at the top of the downstream face but these are less than the allowable tensile stresses.

5 CONCLUSIONS

From these analyses it can be concluded that the dam is stable under normal load and under extreme load conditions.

It is therefore apparent that a dam such as Lake Parramatta may be successfully sized, as a preliminary estimate, using the "cylinder formula" despite the fact that it does not account for uplift (pore pressures) and the other 3-dimensional effects as analysed by finite element analyses.

Also, after 140 years of service and one raising of the dam to a level greater than originally anticipated, it still remains safe and in good sound condition and is a tribute to the engineering abilities of the colony's early engineers.

The dam is therefore a significant engineering heritage site which now serves as a recreational facility for local residents and as an attraction for tourists. It may therefore be of value for the Institution of Engineers to consider preparing a plaque for this dam as an acknowledgment of its unique place in the history of Australian water supply engineering.

Finally, the number of unknowns and intriguing questions raised in this paper about the dams original engineering point to the opportunity for further research on this dam.

6 ACKNOWLEDGMENTS

The authors acknowledge the kind permission of Public Works and Services, Client Services Division, Dams and Civil Branch, for allowing the paraphrasing of parts of their Lake Parramatta Dam Report on Geotechnical Appraisal on 3 Dimensional Final Element Analysis, December 1995 (30) in this paper.

Also acknowledged in preparing this paper is the endorsement of Parramatta City Council and the assistance and guidance received from the staff of the Mitchell Library within the State Library of NSW.

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Appendix C
Attachments:

LORD MAYOR'S OFFICE

JCB:HH
File No G/1070

19 May 1997

Mr Ken Wyatt
Chairman
Engineering Heritage Committee
The Institution of Engineers Australia
Sydney Division
PO Box 138
MILSONS POINT NSW 2061

Dear Mr Wyatt

I have received your very interesting correspondence regarding the Australian Historic Engineering Plaquing Programme and the desire to prepare a nomination of a plaque to the Parramatta Dam.

This project has my full support and I would advise that:

- Public access is available to the dam abutments
- Access can be made available to the nomination party together with historic documentation
- It would be possible to host a small ceremony to unveil the plaque

Therefore, I am pleased to give my approval in principle and would request that the wording on the plaque be made available to Parramatta City Council for its consideration.

Yours faithfully

Councillor John C Books
LORD MAYOR

COUNCILLOR JOHN BOOKS, LORD MAYOR
Council Chambers, Civic Place, NSW 2150 • PO Box 32, Parramatta, NSW 2124, Australia • Tel: 9806 5060 Fax: 9806 5920

The Institution of Engineers, Australia

The Institution of Engineers, Australia
National Committee on Engineering Heritage
Australian National Committee on Large Dams

Australian National Committee on Large Dams
International Commission on Large Dams

Heritage Dams Project

Dear Michael

LAKE PARRAMATTA DAM

Thanks for your fax of 2 July. The proposal to nominate Lake Parramatta Dam for inclusion in the Register of The National Estate was arrived at by comparison of the dam's heritage values against the criteria for significance published by the Australian Heritage Commission. For our project we adopted nine sub-criteria specific to the heritage of dams (see Attachment 1). Note that only a few of these nine sub-criteria can be said to relate directly to engineering qualities or values.

The proposal for Lake Parramatta Dam claimed significance under seven of the nine criteria. The proposal was reviewed by three reviewers independently, two dams engineers and a historian, who ranked it collectively as third in importance in a selection of the top 26 dams in Australia.

I am not able to discuss individual reviewer's rankings (I was one of the reviewers). However in my opinion the dam has national and international significance under a number of the criteria, including engineering and technical significance. I have no doubt that it is a worthy contender for a National Engineering Landmark plaque.

The attached note, based on Paul Heinrichs and the late Dick Ash's proposal, was prepared for the Project Steering Committee who finally endorsed the "top 26" list. It may be of use to you.

With kind regards,

Tony Moulds

Tony Moulds
Project Manager
July 11, 1997

Heritage Dams Project: Project Manager — Tony Moulds, Water Corporation, PO Box 100, Leederville WA 6902
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